A survey on the state of the art of complexity problems for covering arrays

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ABSTRACT

In this paper, a first systematic review and analysis of the current state of the art pertaining to complexity problems for a heavily researched class of designs, namely covering arrays, is presented. In addition to surveying all known complexity results for covering arrays, we formalize many informal notions and related concepts of the related literature. Last but not least, we also correct a number of misinterpretations and false statements which have appeared in the literature, regarding the NP-hardness of some problems related to covering arrays. Respectively, we update the current state of the art, enriching it also with our own results.

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1. Introduction

Covering arrays can be considered generalizations of orthogonal arrays [19] and find practical use, amongst other fields, in the fields of testing software [8], [18], hardware [24] and networks [41]. Additionally they have also been applied in domains, such as material science [42] and genomics [39]. As a consequence a considerable effort has been spent in their efficient construction and also investigating the hardness of related problems.

Some closely related NP-complete problems (e.g. [11], [14], [33] and [38]) suggest that the problem of finding an optimal covering array is a hard combinatorial optimization problem. In general, there is no known strategy to efficiently construct covering arrays with the smallest number of rows or to determine this number for a specific covering array configuration. We will review these and other related problems, in detail, in this work.

In this paper, we investigate the hardness of complexity problems related to covering arrays. First we give some definitions to allow for the presentation of formal complexity problems. This provides the means to distinguish and review the available literature on the subject. For some of these problems, we prove some basic complexity properties such as membership in NP and poly-time relations (between them). In addition, our aim is to clarify some results regarding the complexity of certain problems pertaining to covering arrays as we have identified a number of incorrect statements in the literature, despite some attempts that have been made already in [28] which, as we will show in this paper, are incomplete. For this reason, we additionally conduct a state of the art review of known complexity results for problems related to covering arrays, supplementing it with some new results given in this work.

The paper is structured as follows. In Section 2, we start with preliminary definitions and properties of covering arrays. In Section 3 we give formal statements of complexity problems for covering arrays. We continue in Sections 4 and 5 in the same manner, where we present similar statements for mixed-level and variable strength covering arrays, respectively. Thereafter, in Section 6, we firstly review a result given in [38] and secondly discuss its impact on the problems introduced

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